USE OF HIGH-RESOLUTION SATELLITE IMAGERY TO MAP CORAL REEF ENVIRONMENTS OF THE NORTHWEST HAWAIIAN ISLANDS*

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ABSTRACT

The Northwest Hawaiian islands include 10 islands, atolls, and reefs, extending over 1800 km of the Pacific Ocean and covering over 7000 square kilometers of potential coral habitat. This remote region is currently under national and state management and is being considered for designation as a US National Marine Sanctuary, indicating a need for habitat information. In 1999, high-resolution satellite imagery became available for the first time, introducing a new capability for mapping of benthic habitats. To create maps of the NW Hawaiian islands, we are using high resolution satellite imagery with 4-meter multispectral pixels. The imagery is processed to reduce atmospheric and water surface effects and the results are used to determine bathymetry and to classify the region to up to 16 habitats that have been identified as important by coral reef ecologists. A new method for deriving bathymetry permits extraction of depths to 30 m in clear water, and identification of structural features such as patch reefs and spur and groove. A rule-based classification approach uses a combination of spatial, contextual, and spectral information, as well as field-based knowledge to create the maps, and assures reproducibility. The nominal minimum mapping unit is ~400 square meters--an order of magnitude better than standard visual interpretation. The hierarchical classification scheme includes both structural and cover characteristics. Some of the methods can be translated to Landsat imagery, permitting rudimentary classification (3-5 classes) of some of the extensive deep banks in the area.

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1.0 INTRODUCTION

Detailed, comprehensive benthic habitat maps are a basic tool for characterization and management of coastal ocean regions, including coral reefs. These maps can also be used to locate hazards to marine navigation, provide input for essential fish habitat determinations, establish requirements for and identify potential locations for marine protected areas, and evaluate the actual and potential impacts of human activities, climate variability and extreme environmental events on the reef environment. Comprehensive maps have not yet been developed for the NW Hawaiian islands, which fall under the new Northwestern Hawaii Coral Reef Ecosystem Reserve and have therefore recently come under increased scrutiny. The large area of shallow water habitat and remote location of the islands make mapping by airborne or ship-based surveys impractical for this region. Multispectral satellite imagery with high spatial resolution offers a promising alternative and is being used as the primary technology for mapping this area.

2.0 APPROACH

Satellite imagery will be incorporated into the assessment and monitoring of the NW Hawaiian coral reef habitat in several different stages, following the specific steps outlined below. The first stage involves generating draft maps from satellite imagery and limited field data, using techniques that maximize use of available information and expedite map production. The procedures are designed to be both objective and reproducible. The second stage includes validation of the maps through external review and refinement as necessary though inclusion of additional satellite, airborne or field data. The final stage is to incorporate satellite imagery into long-term monitoring programs.

- Obtain medium and high resolution multispectral satellite imagery, using high resolution for shallow atolls and medium resolution for deep, but optically visible banks.
- Accurately georeference the imagery, using satellite orbital parameters and sophisticated image processing models. Refine the positioning with ground control data if available. Improve positioning for areas with vertical relief by incorporating a digital elevation model (DEM), if available.
- Calculate reflectance, correcting for atmospheric and water surface effects. Derive bathymetry from the imagery and use the depth information to correct reflectance for water column effects.
- Use rule-based classification process to create habitat map, incorporating reflectances, derived or externally obtained bathymetry, and field data.
- Solicit input from regional experts to validate and refine the draft maps.
- Obtain additional imagery to fill in areas with cloud cover. Classify new imagery with same procedure and merge results, creating cloud-free images, bathymetry and habitat maps.
- Target areas requiring additional field work and merge additional field data into maps as it becomes available.
- In accordance with long-term monitoring plans, acquire additional imagery at specified intervals and use change analysis to identify areas that have been modified. Map targeted areas, using the same procedures used to make the original maps, for consistency.

3.0 RESULTS

Figure 1 provides an example of the draft habitat map generated for Midway Islands in Northwest Hawaii. This map was produced using high resolution IKONOS satellite imagery and field data obtained from a National Ocean Service research cruise to Northwest Hawaii in Aug-Sep 2001. Similar maps are being generated for nine of the other atolls in the region, using high-resolution IKONOS imagery for the shallow areas and medium-resolution Landsat imagery for deep (~25-35 m) platforms, such as those surrounding Gardner Pinnacles.

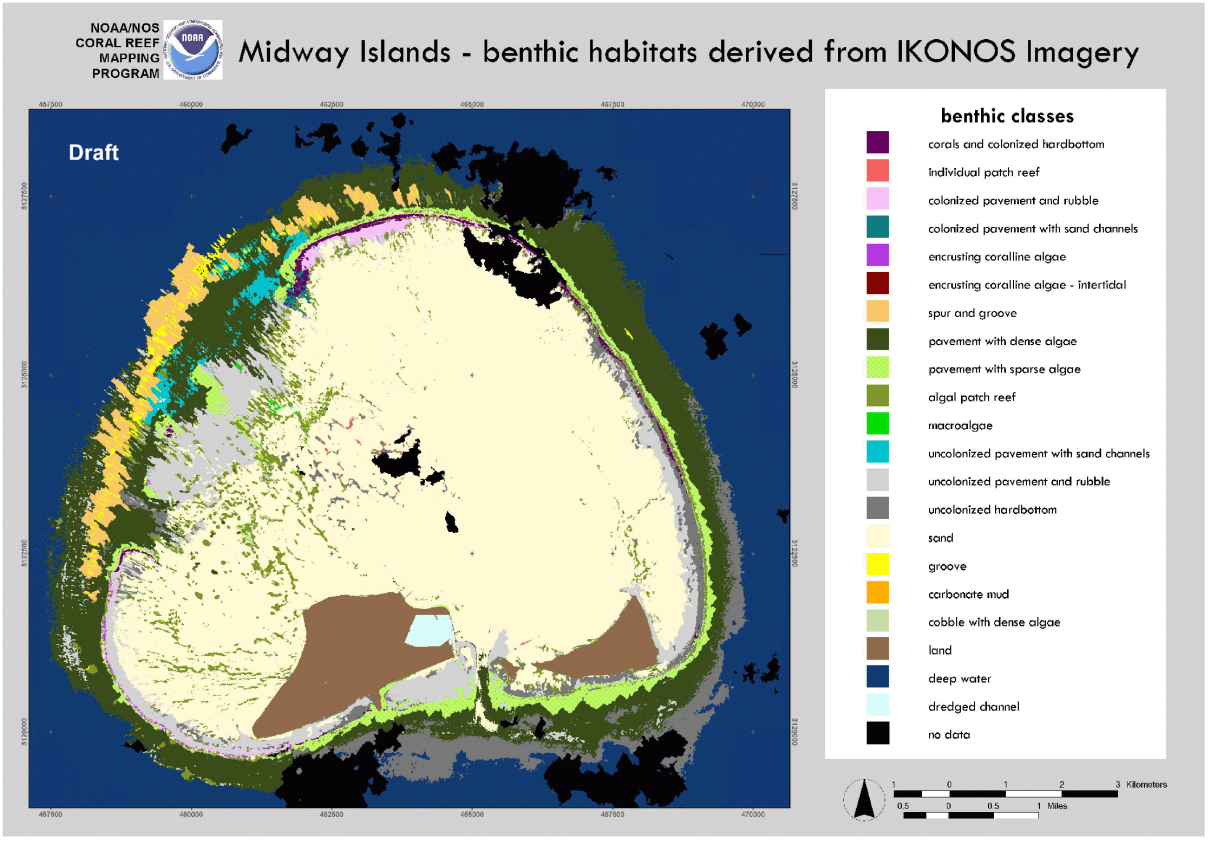

Figure 1. Draft Benthic Habitat Map for Midway Islands, NW Hawaii